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NRL Code/5309 Memo dtd 20 Feb 1977

AD NUMBER
AD529812
CLASSIFICATION CHANGES
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31 Dec 1993 per document markings

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NRL Report 7684
Copy No. 67

AD529812

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Second Fleet Surveillance Another Exercise in Fleet Air Defense
[Unclassified Title]

F. H. UTLEY, W. C. HEADRICK, J. A. HOFFMEYER, AND M. S. LIEBERMAN

Radar Techniques Branch
Radar Division

April 9, 1974

NAVAL RESEARCH LABORATORY
Washington, D.C.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Report 7684	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SECOND FLEET SURVEILLANCE--ANOTHER EXERCISE IN FLEET AIR DEFENSE [Unclassified Title]		5. TYPE OF REPORT & PERIOD COVERED An interim report on one phase of a continuing NRL problem. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Frank H. Utley, William C. Headrick, James A. Hoffmeyer, and Melvin S. Lieberman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NRL Problem R02-23
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Navy Office of Naval Research Arlington, Virginia 22217		12. REPORT DATE April 9, 1974 13. NUMBER OF PAGES 14
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) SECRET 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE XGDS-3-1993

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Over-the-horizon (OTH) radar
Fleet air defense (FAD)
Computer tracking algorithm
Ocean surveillance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

[Secret]

(S) NRL deployed the Madre radar in a surveillance mode over the Atlantic Ocean transit of the USS *Independence* (CVA-62) in September 1971 for a period of six days. Exercise results are cited which give a resume of air contacts, corroboration of contacts with FAA records, and warning-message formulation and subsequent relay to the CVA-62. Operational deficiencies in azimuth assessment and communication procedures are noted. Experience with an aircraft-tracking algorithm in a multipath environment is examined.

(Continued)

20. Abstract (Continued)

(S) Corrective modifications to the Madre equipment, including monopulse receivers, monopulse-processing-channel development, chirp emissions, low-data-rate communications, and backscatter monitor, which will all enhance the Madre fleet-air-defense (FAD) posture, are described briefly.

CONTENTS

SECOND FLEET SURVEILLANCE
ANOTHER EXERCISE IN FLEET AIR DEFENSE
[Unclassified Title]

INTRODUCTION

(S) Since NRL's detection of the USS *Forrestal* (27 knots) and the merchantman *Grotedyke* (17 knots) in the summer of 1968 (1), interest has been stimulated at NRL and elsewhere to promote over-the-horizon (OTH) surveillance in solving the Fleet Air Defense (FAD) problem. NRL has enjoyed several successful interactions with elements of the Second Fleet in simulated FAD scenarios (2). The Stanford Research Institute, through its experiments with First Fleet units (3) as well as with container ships plying the Pacific Ocean to South Viet Nam, has generated an awareness of the use of an OTH sensor for ocean surveillance (4). The efforts of the OTH community should bring forth more experimental evidence to convince naval planners to consider OTH as a solution to one of the Fleet's most pressing problems.

(S) It is the purpose of this report to review, in part, a FAD exercise in which NRL cooperated with COMSECFLT to provide OTH surveillance of the USS *Independence* (CVA-62) during her transit of the Atlantic Ocean in September 1971. A description of the OTH radar coverage for the six-day exercise is given in addition to corroboration of NRL radar data points with FAA position points. A summary of warning-message traffic is examined on the basis of separation distance of the "threat" and the CVA-62. A brief description is given of the NRL computer tracking algorithm along with tracking results for September 23, 1971.

(S) Inadequacies in NRL's FAD capability are cited. Current work, as well as envisioned modifications, are shown to enhance slow-ship discrimination, aircraft-azimuth estimation, and real-time communication.

EXPERIMENTAL RESULTS

(S) The radar coverage of the operating area of the USS *Independence* during the period from September 19 through September 24, 1971, is depicted in Fig. 1. The horizontal lines in this figure indicate the range extent covered by the Madre radar during the daylight hours of operation of the system. Unusually good propagation conditions prevailed during the observation period on September 23. A two-hop propagation mode permitted the detection of many commercial air carriers over the North Atlantic at ranges in excess of 200 naut mi. During the period from 1100 through 2230 GMT on the 23rd, the USS *Independence* was steaming on a northeasterly course at a range of from 1960

Note: Manuscript submitted October 26, 1973.

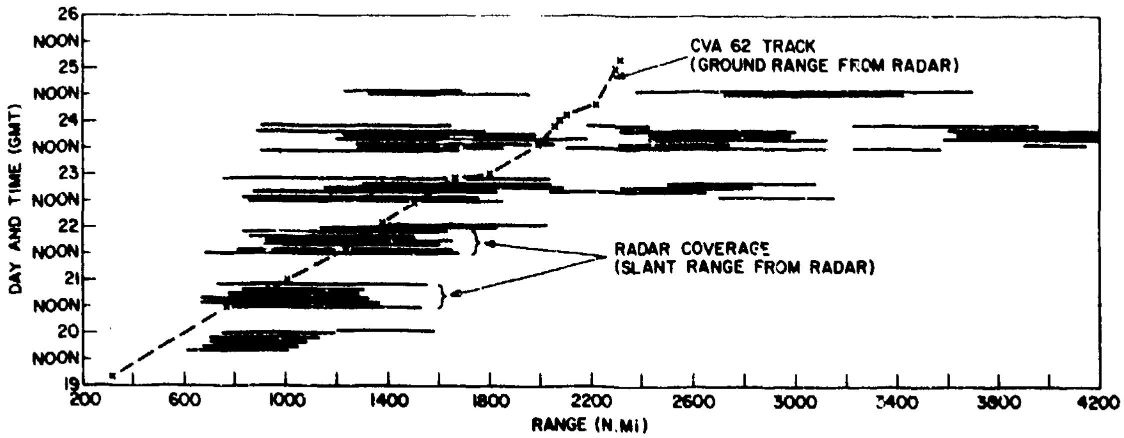

Fig. 1 (S)—Radar coverage for the CVA-62 transit

to 2070 naut mi from the Madre site on the Chesapeake Bay. It was during this period that 33 warning messages of approaching aircraft were passed to the ship.

(S) Figure 2 is a photograph taken of the doppler-vs-range display at 1704 GMT on September 23. Several aircraft are clearly discernible, as indicated by the arrows in the figure. In addition to these aircraft, there are a number of others that are unlabeled. The vertical trail of echoes to the right of the range strobe at about 1836 naut mi is likely to be a meteor echo. The large dispersed signal at about 2096 naut mi is also likely to be a meteor echo. Occasionally a large and/or high-velocity meteor can cause an overdense ionization trail which may persist for seconds or even minutes. Often these trails will collapse slowly and appear on the display as becoming less spread in doppler with each radar integration period. Just prior to disappearance, the discreteness in doppler of the meteor-trail return may be such that it strikingly resembles the typical oblong characteristic shape of an aircraft return. The trained operator should have little difficulty in distinguishing between the two if he has been alert to note the location of the meteor when it was more dispersive in doppler.

(S) Figures 3 and 4 are plots of slant range vs time, which depict the track of the USS *Independence* between 1300 and 2300 GMT on September 23. Additionally the tracks of westbound air traffic (plus two eastbound aircraft), as deduced from flight strips provided by the Gander Air Traffic Control Center, are plotted in these figures. Because of the density of the traffic, it was decided to plot some of the tracks on a separate figure (Fig. 4) to maintain the discreteness of the tracks. Data points as provided by the Madre system are also plotted. For the period of time that the Madre system was operated on the 23rd (from 1130 to 2300 GMT), good agreement can be seen between the Madre data and the tracks are plotted from information provided by the Gander Air Traffic Control Center.

(S) During the five-day interval from September 19 through 23, 54 messages were passed to the USS *Independence* warning the ship of approaching aircraft; a summary of these messages is provided in Table 1. Figure 5 charts the number of aircraft reported vs the range interval from the ship to the aircraft existing at the time each aircraft was reported. The detection of 25 aircraft at ranges beyond 200 naut mi demonstrates the use

Fig. 2 (S)—Doppler-vs-range display at 170400 GMT with multiple aircraft in view

of an OTH radar as a means for early-warning detection of hostile aircraft at ranges outside the range capabilities of air search radars currently used aboard ship. This capability coupled with a real-time system for communicating this information to a ship operating under emission-control (EMCON) conditions would be a great asset to Fleet Air Defense.

COMPUTER TRACKING OF AIRCRAFT TARGETS

(S) NRL has been active in evolving a computer tracking algorithm in the recent past. This software at present does not run in real time with operator-designated targets or with automatically acquired targets. The program accepts as an input manually extracted aircraft-data-point triplets—time, range, and doppler frequency. The algorithm as presently configured accomplishes track synthesis by attempting a match both in doppler and range of a given candidate point with those values believed consistent for a prior data point or last point in a current track. Prediction is accomplished only in the range parameter. Doppler predictions will be implemented shortly.

(S) The program is versatile in that it permits various tolerances to be flexible. Range estimates, doppler tolerances, and the time to drop a track are all modifiable parameters.

(S) Figure 6 is a range-time plot generated for the time 1515 to 1740 GMT for data extracted from tape records for September 23, 1971. Data were unavailable between 1651 and 1703 GMT. The total number of tracks plotted is 51. This should be qualified:

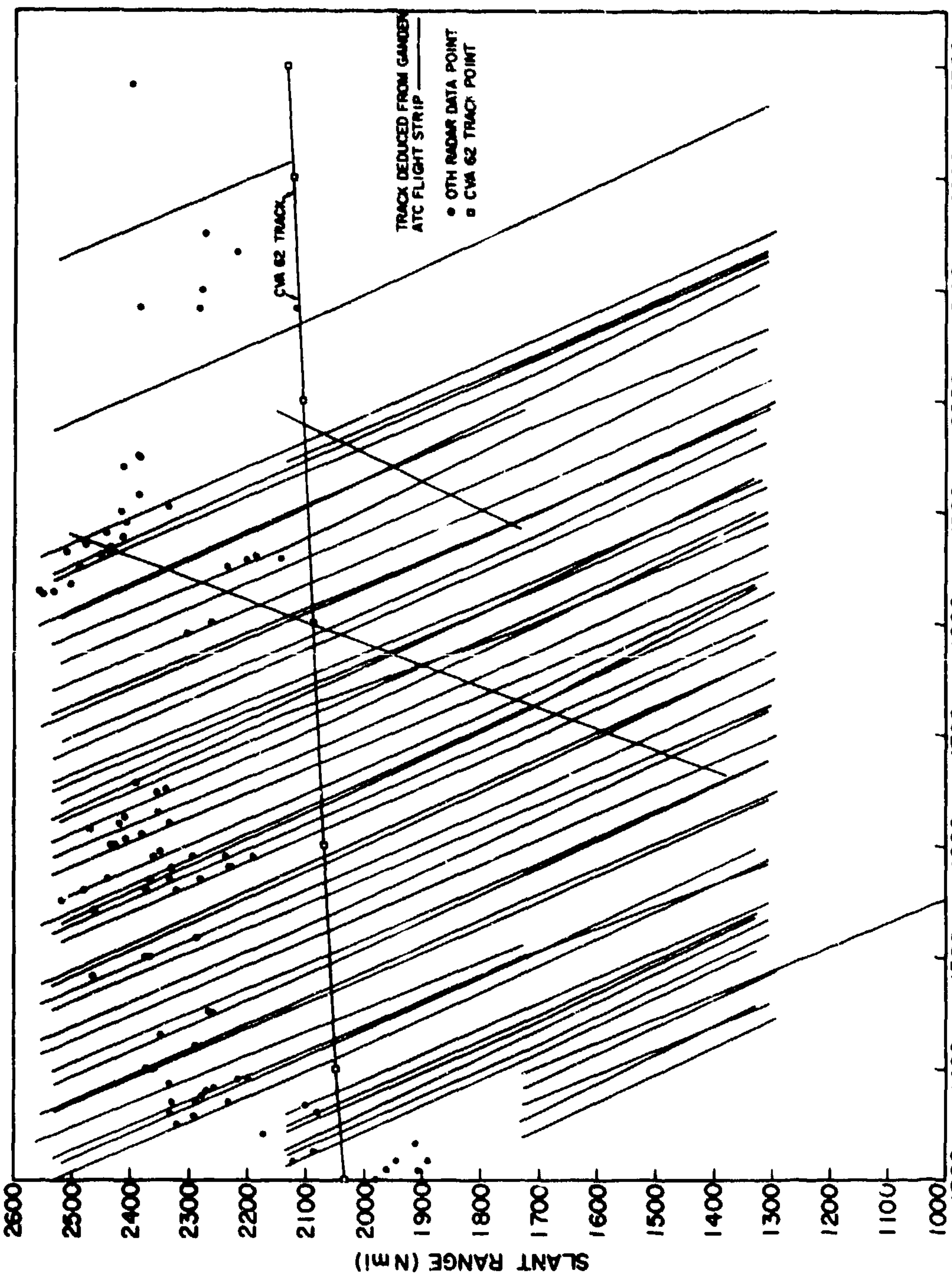

Fig. 3 (S)—North Atlantic air traffic westbound for Sept. 23, 1971 (Part 1)

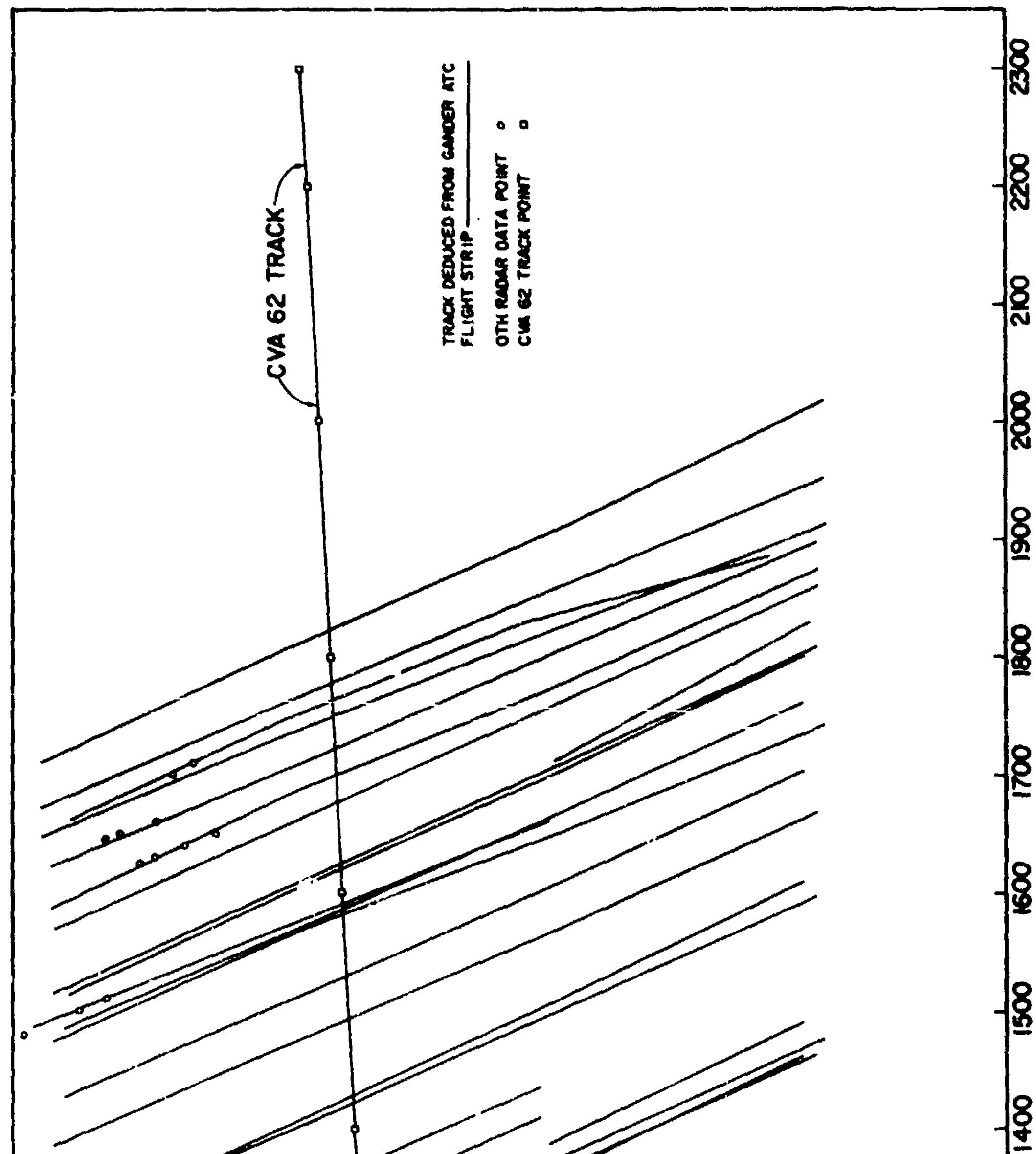

Fig. 4 (S)—North Atlantic air traffic westbound for *Sept. 23, 1971* (Part 2)

Table 1 (S)
Reports of Approaching Aircraft Made to the USS *Independence*
During the Period Sept. 19 to Sept. 23, 1971

Date	Radar Assessment Time (GMT)	Ground Range (naut mi)	Time Message Passed (GMT)	Time Differential = Radar Assessment Time to the Time Message Passed (min)
19	1952	851	2010	18
	1952	747	2010	18
	2020	927	2032	12
	2040	855	2051	11
	2130	682	2137	7
	2205	696	2212	7
	2237	675	2243	6
20	1650	990	1700	10
	1710	1180	1717	7
	1730	899	1737	7
	1733	1092	1745	12
	1853	1018	1857	4
	1910	974	1921	11
	1935	958	1942	7
	1956	1113	2002	6
21	1732	1307	1753	21
22	1342	1594	1350	8
	1355	1602	1408	13
	1355	1684	1408	13
	1540	1594	1556	16
	1545	1616	1556	11
	1607	1675	1614	7
	1623	1745	1636	13
23	1310	2060	1334	24
	1315	2025	1334	19
	1325	2115	1334	9
	1335	2235	1343	8
	1340	2040	1403	23
	1345	2220	1350	5
	1350	2200	1355	5
	1352	2157	1403	11
	1402	2301	1412	10
	1430	2207	1435	5
	1459	2312	1503	4
	1542	2220	1550	8

Table continues

Table 1 (S) (Continued)

Date	Radar Assessment Time (GMT)	Ground Range (naut mi)	Time Message Passed (GMT)	Time Differential = Radar Assessment Time to the Time Message Passed (min)
23	1548	2170	1553	5
	1557	2290	1607	10
	1600	2370	1607	7
	1603	2345	1612	9
	1615	2335	1619	4
	1628	2297	1639	11
	1633	2330	1639	6
	1758	2217	1806	8
	1817	2467	1836	19
	1834	2140	1848	14
	1838	2435	1848	10
	1847	2385	1857	10
	1900	2355	1911	11
	1902	2275	1911	9
	1929	2322	1935	6
	2050	2223	2104	14
	2050	2325	2104	14
	2100	2200	2104	4
	2120	2160	Message not forwarded	—
	2130	2215	Message not forwarded	—
	2250	2340	2259	9

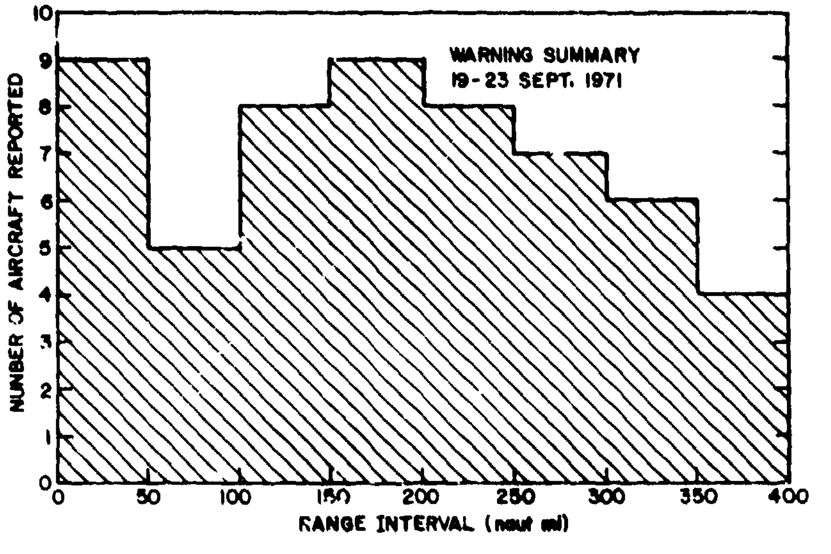

Fig. 5 (S)—Number of aircraft reported vs the range interval from the ship to the aircraft

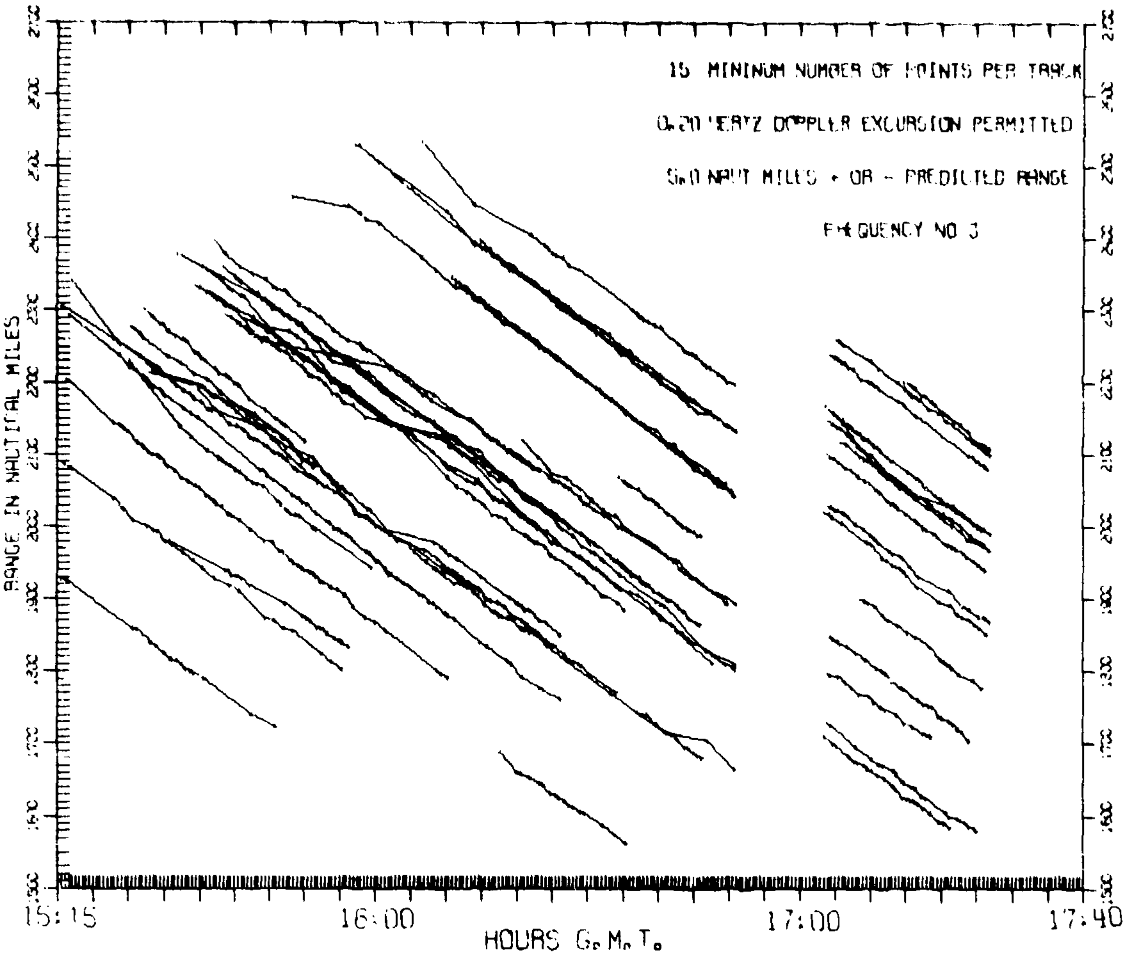

Fig. 6 (S)—Computer-synthesized range-vs-time tracks for Sept. 23, 1971, 1515 to 1740 GMT

even though several of the tracks beyond the data gap are obviously extensions of tracks existing earlier in the record, the machine counts such a track as two tracks; hence there are 51 tracks. The tolerances used for this plot are shown in the upper right-hand corner. No tracks are shown that possess fewer than 15 points. The doppler is allowed to change by ±0.2 Hz between consecutive track points. The tolerance on the predicted range point is ±5 naut mi/min for the maximum unambiguous doppler target. The range tolerance is scaled for slower targets.

(S) Some of the tracks persist for an hour or more. In several areas of the plot there seem to be several tracks that are close spaced. The reason for this has not been fully resolved. It is believed that multipath echoes may be contaminating the track synthesis by giving parallel close-spaced tracks. At the ranges of these targets the Madre radar beam is likely several hundred miles broad. It is also conceivable that multiple aircraft at dissimilar azimuths within the radar beam could supply such confusion of tracks. Intensive investigation as to the mechanism is indicated.

(S) In the manual extraction (a tedium) of the more than 3100 data-point triplets, it was determined (on the basis of the algorithm configuration) that data acquired at too frequent an interval precipitated a disruption in track continuity. When the 10-second spaced data was critically examined, it was determined that short-term ionospheric-path instabilities were more prominent than aircraft motion, the net effect of the anomaly being that the aircraft echo would move a disproportionate distance in the short elapsed time and would hence exceed the predicted range (within tolerance). When samples were taken every 30 s on each available target, the track disruption noted was relieved. Improper inferences should not be made from these considerations. It is very possible that a more adaptive tracking program would accommodate some of these anomalies.

(S) Figure 7 is a plot of a housekeeping parameter which is maintained by the program for each track. The software computes a running average of the elapsed time between points of a given track. When the track is dropped, the cumulative average is printed. The population distribution of these average times between points for the 51 tracks of Fig. 6 is shown in Fig. 7. It is rather interesting that the elapsed time between track points peaks at around 80 s. The reason for the average being so large is not known at present. A study is being made to ascertain if any subtle idiosyncrasy of the algorithm is involved.

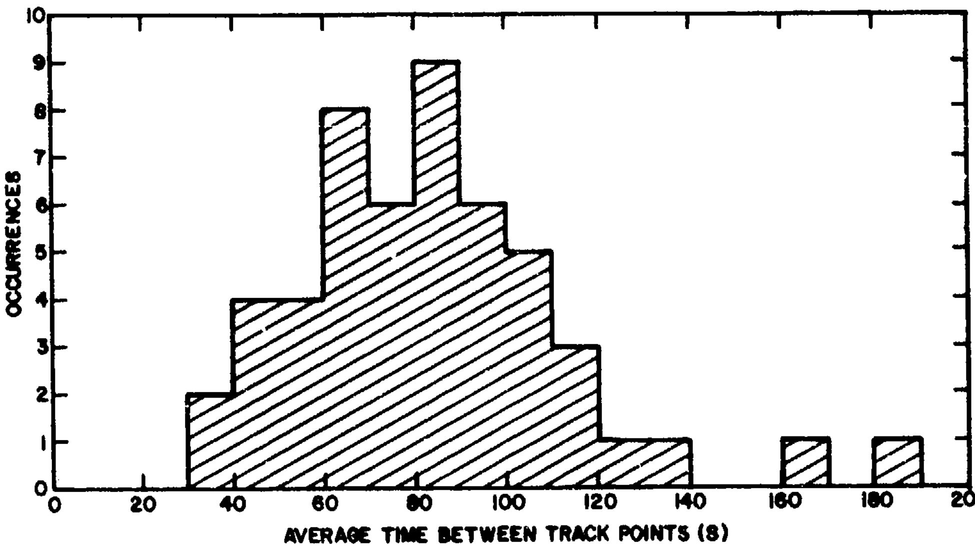

Fig. 7 (C)—Number of occurrences vs average time between track points

REFLECTIONS

(S) In the Fleet exercise reported in the preceding, certain deficiencies were noted:

- Too large a delay in reporting the warning message to the operations control center in Norfolk. This excessive delay was due to the necessity of encrypting the message in NATO numerical code and passing it over a telephone circuit. In contrast to the rather long delays experienced in the USS *Independence* exercise, the USS *Wasp* exercise was conducted with a real-time phone circuit between the radar site and the ship group. Warning-message delays were no more than 1 to 2 min.

- Inability to detect the USS *Independence* at all times. The ship was distinguishable from the clutter part of the time, however a reduction in resolution-cell size would have increased the amount of time that the ship was visible.

- Excessive beamwidth dimension, which compounds a high-density scenario. A narrower receiving bandwidth would have been desirable.

(S) In response to these previously mentioned deficiencies, certain corrective modifications are being made. Additional improvements are envisioned consistent with funding:

- The Naval Electronic Systems Command (NAVELEX) is funding a program for developing a communication modem at NRL. The implementation of this device will permit the reception of phase-coded transmissions (on the radar pulse), resulting in a very reliable low-data-rate (75-baud) channel.

- Modifications are now being made to the wide-band exciter (WEX) to permit the generation of the phase-coded transmissions mentioned previously as well as chirp waveforms. Compatible receiver channels are being developed in parallel to process the chirp waveforms.

- NAVELEX has funded the development of monopulse receiver channels, as well as modifications to the signal processor, to permit the analysis of monopulse information. Monopulse angle estimates dependent on target signal to noise may permit angle specification to 0.2 of the radiation beamwidth or at times to perhaps 0.1. This assessment will be performed on one operator-designated target per integration period.

(S) Figure 8 gives conceptual meaning to an integrated system permitting the real-time detection of slow targets (ships) or conceivably small fast targets (ASM) and the specification of location of those targets in latitude/longitude (or in ship-oriented coordinates), with concurrent real-time relay of the threat scenario to friendly forces.

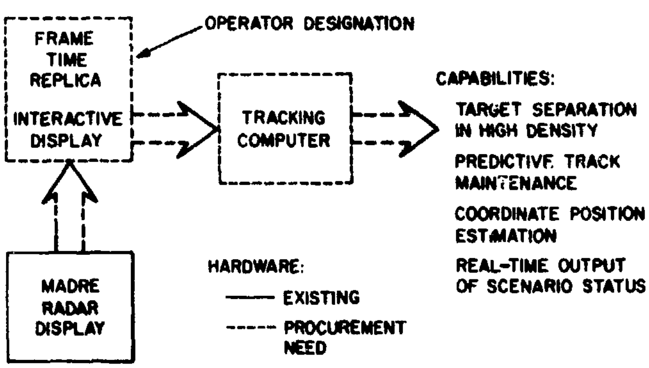

Fig. 8 (S)—Real-time, computer-aided track synthesis for the operator designated targets

SUMMARY

(S) NRL continues to be excited about potential capability resident in the OTH sensor to accomplish:

- Real-time FAD
- Wide ocean surveillance.

With the system improvements cited previously, the Madre radar should be able to accomplish the objectives implicit in Fig. 8.

REFERENCES

1. J.M. Headrick et al., "Skywave-Path Quality, Including Doppler Capabilities for Ships and Slow Targets," in *Proceedings of the OHD Technical Review Meeting*, Oct. 23 - 25, 1968.
2. F.H. Utley et al., "On the Surveillance Potential of an HF Radar," in *Proceedings of the OHD Technical Review Meeting*, Mar. 17 - 18, 1971.
3. J.R. Barnum, " 'Ship Ahoy' Summary Through March 1972 (Secret report, unclassified title)," *Stanford Research Institute Technical Report 17*, Aug. 1972.
4. J.R. Barnum, "Ship Surveillance," in *Proceedings of the OHD Technical Review Meeting*, May 3 - 4, 1972.

MEMORANDUM

20 February 1997

Subj: Document Declassification

Ref: (1) Code 5309 Memorandum of 29 Jan. 1997
(2) Distribution Statements for Technical Publications NRL/PU/5230-95-293

Encl: (a) Code 5309 Memorandum of 29 Jan. 1997
(b) List of old Code 5320 Reports
(c) List of old Code 5320 Memorandum Reports

1. In Enclosure (a) it was recommended that the following reports be declassified, four reports have been added to the original list:

Formal: 5589, 5811, 5824, 5825, 5849, 5862, 5875, 5881, 5903, 5962, 6015, 6079, 6148, 6198, 6272, 6371, 6476, 6479, 6485, 6507, 6508, 6568, 6590, 6611, 6731, 6866, 7044, 7051, 7059, 7350, 7428, 7500, 7638, 7655. Add 7684, 7692.

Memo: 1251, 1287, 1316, 1422, [redacted], 1500, 1527, 1537, 1540, 1567, 1637, 1647, 1727, 1758, 1787, 1789, 1790, 1811, 1817, 1823, 1885, 1939, 1981, 2135, 2624, 2701, 2645, 2721, 2722, 2723, 2766. Add 2265, 2715.

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2. The above reports are included in the listings of enclosures (b) and (c) and were selected because of familiarity with the contents. The rest of these documents very likely should receive the same treatment.

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